Noise exposure from leisure activities: A review

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Over the past two decades there has been increasing concern about the role of nonoccupational, or leisure noise on hearing. This paper reviews published studies that detail the noise levels and potential effects of some noisy leisure activities. Considered are the most common sources of leisure noise: exposure to live or amplified rock, classical, or jazz music; exposures from personal listening devices ("walkman" type); noise around the home, and hunting and target shooting. Although all activities listed above have the potential for dangerous levels of noise exposure, the most serious threat to hearing comes from recreational hunting or target shooting.

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INTRODUCTION

Our environment is filled with noise. Noise exposure associated with the workplace has been known to produce hearing loss for centuries. In fact, "boilermaker's deafness" was the term coined to describe the now familiar bilateral high-frequency sensorineural hearing loss associated with excessive exposure to occupational noise. Field studies of hearing loss in industrial workers (e.g., Taylor *et al.*, 1965; Burns and Robinson, 1970; Johnson, 1978), combined with laboratory studies of noise-induced hearing loss in human and animal subjects (see Melnick, 1991, and Clark, 1991, for reviews), led the U.S. Department of Occupational Safety and Health to promulgate regulations that limited occupational exposure to noise (Department of Labor, 1983) and provided for the protection of hearing in employees who worked in environments where the employee's noise exposure exceeded an 8-h time-weighted average of 85 dBA.

These regulations were aimed at protecting the vast majority of the workforce from sustaining a "material impairment in hearing" after a working lifetime of 40 years. However, with the exception of the mandate requiring education of employees about the effects of excessive exposure to noise, the regulations fail to consider an employee's exposure to noise during nonworking hours, and this may be important. Evidence has been mounting over the past two decades that there are sources of noise exposure outside the workplace that are potentially damaging. Precisely what the effects of these exposures are on eventual noise-induced hearing loss has been the topic of many studies (see Kryter, 1986, for review of sociocusis). Obviously, implicit in the assessment of the role of nonoccupational or recreational noise in NIHL is a determination not only of the level of exposure possible, but also some information about the typical exposure level and pattern for groups of listeners.

There are numerous sources of nonoccupational noise exposure. A partial list of significant sources and maximum levels of nonoccupational noise is given in Fig. 1 from Clark and Bohne (1984). If one considers a reading of > 90 dBA as the borderline between "safe" and "dangerous" noise exposures, it is seen that nearly everything on the list, with the exception of household items such as refrigerators, falls in the "dangerous" category. Information about maximum levels does not, in and of itself indicate a dangerous noise exposure (unless the continuous level exceeds 140 dB SPL); the hazards from exposure to noise from any device listed in Fig. 1 depend upon the level and the duration of exposure for

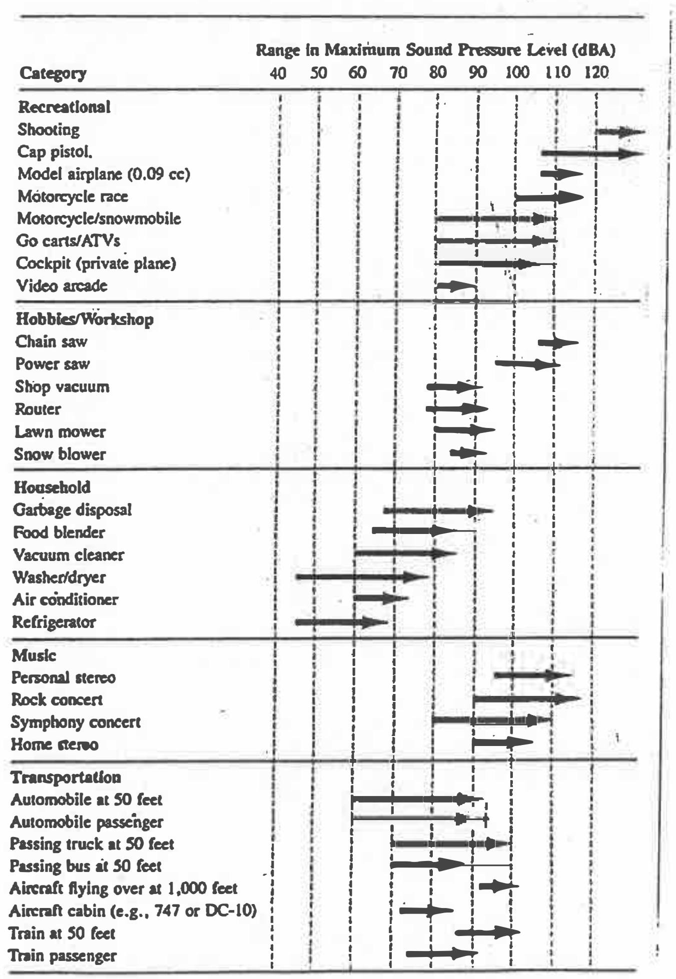

FIG. 1. Range of maximum sound levels in dBA measured from common recreational, household, hobby, and transportation noises. [Reprinted by permission from Clark and Bohne (1984).]

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a typical consumer of that noise.

The purpose of this review is to summarize the literature concerning recreational, or nonoccupational, exposure to noise. An exhaustive review of all the literature concerning nonoccupational exposure to noise is beyond the scope of this paper. However, the reader is referred to the excellent summary prepared by Davis *et al.* (1985). The Davis review contains evaluations of 582 original publications on the topic. This review will be limited to what may be considered as the major sources of recreational noise exposure: attendance at rock, big band, or symphony concerts; music listening through headphones (i.e., Sony Walkman); noise around the home (chainsaws, power tools, lawnmowers, leaf blowers, etc.), and noisy hobbies (i.e., hunting or target shooting). For each type of exposure, we consider the data on noise immission by the particular source, some information about the frequency of use by typical listeners, an assessment, where possible, of the damage risk posed by the exposure, and finally some statements about the quality of the studies.

I. EXPOSURE TO MUSIC

A. Discotheques and rock concerts

There have been a number of studies published within the past two decades that are concerned with exposure from discotheques and attendance at rock concerts. The reported sound levels (dBA) from a number of these studies is reproduced in Fig. 2. The geometric mean of all measured sound levels is 103.4 dBA. In general, it is reasonable to conclude that attendees at rock concerts or noisy discotheques are routinely exposed to sound levels above 100 dBA. Studies of

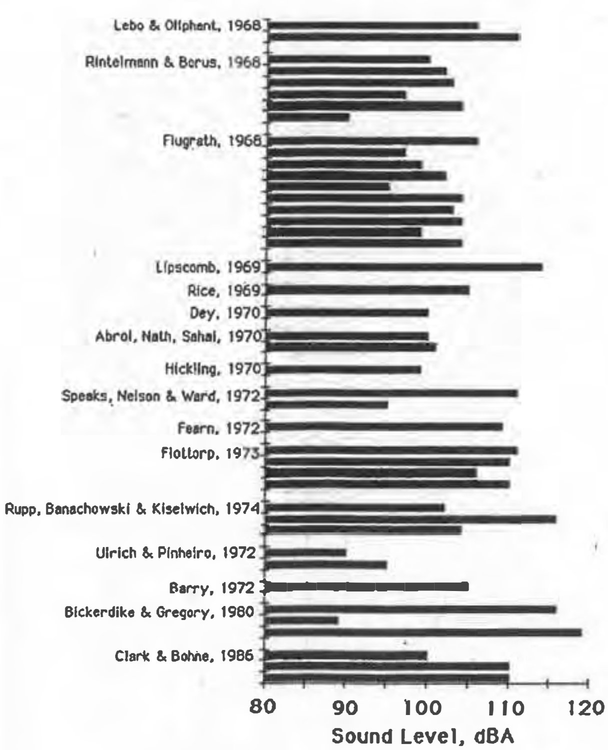

FIG. 2. Bar chart showing the published levels of rock music from 16 studies. The geometric mean of the reported levels is 103.4 dBA.

temporary threshold shift (TTS) after exposure to rock music have most often considered only the hearing levels of performers (Rintelmann and Borus, 1968; Redell and Lebo, 1972; Axelsson and Lindgren, 1977). A few studies have shown TTS's in listeners attending rock concerts (e.g., Rintelmann *et al.*, 1972; Ulrich and Pinheiro, 1974; Clark and Bohne, 1986; Danenberg *et al.*, 1987). Generally, these studies show that most listeners sustain moderate TTSs (up to 30 dB at 4 kHz) that recover within a few hours to a few days after the exposure. Because hearing losses in performers, concessionaires, engineers, and employees of discotheques are occupational, they are not considered relevant to this review, although it is recognized that while a 100-dBA exposure for a few hours weekly or monthly presents little risk to the attendee, it may represent significant risk of noise induced hearing loss (NIHL) to employees who are exposed on a daily basis.

A basic question often asked is why do listeners tolerate such noisy environments as rock concerts and noisy discotheques. Anecdotal reports from the press and the popular literature suggest the young people consider noisy environments as "exciting" and consistent with exuberant behavior. Calvert and Clark (1983) have coined the term "social noise phenomenon" to describe the tendency of youths and young adults to frequent noisy discotheques. They hypothesized that because high levels of noise prevent communication at distances of greater than a few feet, individuals who seek to meet members of the opposite sex may prefer this noisy environment where they are not required to display their intelligence, wit, and social skills. Noise then becomes an equalizer that depersonalizes the environment for everyone. A corollary to this hypothesis is evident from a consideration of the typical discotheque environment. Dancing, commonly associated with discotheques, is the only social activity that permits a couple who are not acquainted to touch and embrace each other, a behavior that may be desirable but is otherwise considered socially unacceptable; high levels of noise in discotheques similarly encourage individuals to move inside the "personal space" in order to communicate.

B. Classical music and jazz

Although NIHL may occur in musicians exposed to classical music (e.g., Axelsson and Lindgren, 1981), studies that considered typical exposures to attendees all showed average exposures of less than 90 dB (Lebo and Oliphant, 1968; Barry and Thomas, 1972; Fearn, 1975). Given that even the most enthusiastic concert-goer most likely could not exceed 20 h per week of exposure, it is unlikely that attending classical music concerts poses any risk of NIHL for anyone.

A search of the literature concerning jazz and big band music, which is often performed in smaller amphitheaters than rock concerts or symphony concerts, failed to disclose any data on typical exposure levels for attendees. However, during the preparation of this manuscript the author had the opportunity to attend a big band concert featuring the Woody Herman Band. The 2-h concert was performed in a 500-seat auditorium that was approximately 90% filled. During the concert, the author wore a Quest M-27 noise logging dosimeter placed on his right shoulder; he was seated in the third row, directly in front of the band. The distribution of the 1-min average levels obtained are shown in Fig. 3. The average level for the 2-h event (Leq) was 96.1 dBA; 1-min levels above 90 dBA occurred 53.4% of the time, and 16 min were above 100 dBA. The dose, calculated by OSHA standards (90-dB criterion, 80-dB threshold, 5-dB trading ratio) was 37% of the permissible exposure level. The time history of the levels is shown in Fig. 4.

These data indicate that noise exposure from jazz concerts exceeds that from symphony concerts, but falls short of that typically experienced by attendees at rock concerts. For all these kinds of music exposure, it is unlikely that an individual will have a significant risk of developing significant NIHL from that exposure alone.

II. LISTENING THROUGH PERSONAL CASSETTE/STEREO PLAYERS

Increased use of personal stereos and cassettes (Sony Walkman-type radios), particularly in youths and children, has led to general concern about potentially hazardous exposures. Informal surveys by the author in elementary school classrooms has indicated that 80%–90% of 4th- to 6th-grade students own and use personal listening devices. Media attention, concern by parents, and most likely potential product liability have led some manufactures to include warnings in the instruction manual that caution against prolonged listening at high-volume levels. Because many workers in otherwise boring manufacturing environments choose to wear personal stereo systems (PSSs) on-the-job, an additional concern is that these devices may contribute unacceptably to an employee's noise dose (Skrainar *et al.*, 1987).

In general, the quality of studies in the literature that address hazards of exposure from PSSs is variable. A summary of the findings of several studies is presented in Table I. Early reports by Wood and Lipscomb (1972), and Katz *et al.* (1982) considered only the maximum levels attainable from personal hi-fi headphones; no attempt was made to determine "typical" levels or to assess frequency or duration of exposure. Furthermore, the reported SPLs were measured on a 6-cc NBS 9A coupler; it is known that the NBS 9A coupler pressure measures approximate ear canal pressures only when an appropriate earphone (such as the TDH 39 on an MX 41A cushion) is used. Wood and Lipscomb reported SPLs as high as 124 dBA from earphones and Katz reported maxima of 110–128 dBA. Based solely on the observation that maximum levels exceeded the OSHA 90-dB criterion for an 8-h workday (DOL, 1983), both papers concluded that earphone listening represented a hazard to hearing. Although this conclusion may be correct, it was not warranted by the data presented.

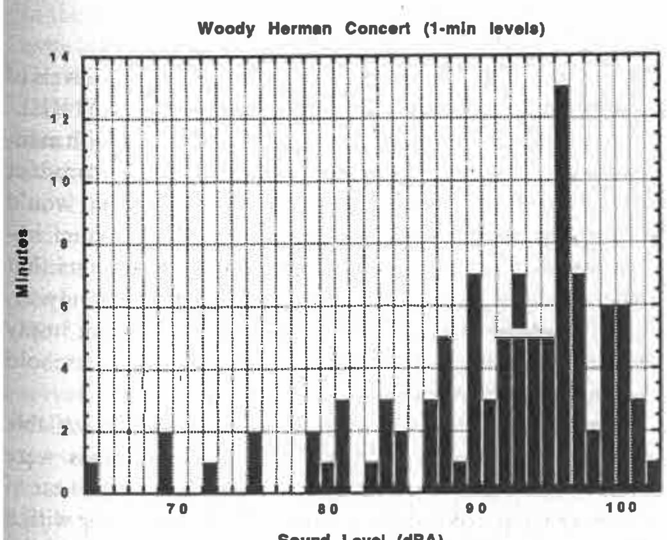

FIG. 3. Distribution of 1-min average sound levels measured from the audience (center, third row) during a concert by the Woody Herman Band at the Sheldon Theatre, St. Louis, Mo., November 1989.

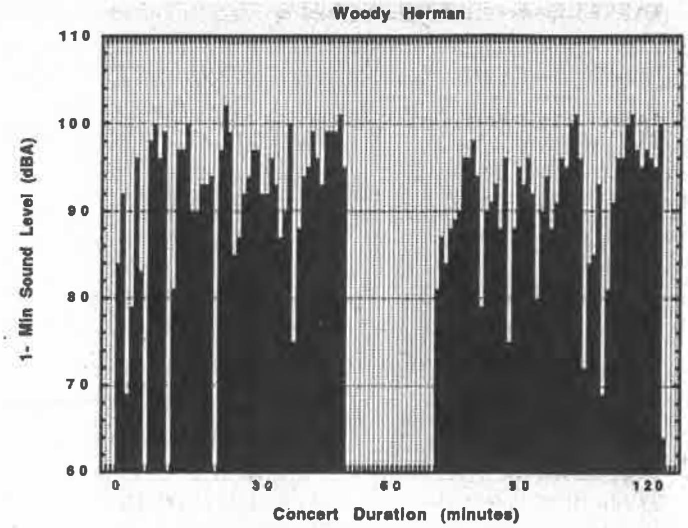

FIG. 4. Plot of the time history of 1-min average sound levels (dBA) during the concert described in Fig. 3.

More relevant than the maximum levels attainable is some estimation of the levels actually set by listeners. Kuras and Findlay (1974) asked self-described rock music fans ages 18–25 to judge preferred listening levels (MCL) and uncomfortable levels (UCL) for "Whole Lotta Love," by Led Zeppelin, and for a tape of the listener's choice. All subjects reported listening behavior of at least 30 min, 4 or more times per week. Listeners reported a mean MCL for the set piece of 92.7 dBA and 88.1 dBA for the choice piece; of the 75 choices made, only 10 exceeded 100 dBA, and only 2 approached the 122-dBA figure reported by Wood and Lipscomb. The authors concluded that it is questionable whether any significant noise-induced hearing loss would result from exposures to rock music at the preferred levels for the majority of listeners unless the exposures continued for several hours daily over several years.

In Appendix II of their review, Davis *et al.* (1985) reported the results of a study of preferred ear-canal SPLs for PSSs in young listeners (21–22 years old) under two conditions: when music listening is a background activity for some other activity; and when the music is the main item of interest. Listeners who used music as a background selected levels that averaged 74.2 dB SPL (s.d. = 7.06); when music

TABLE I. Studies of personal stereo systems.

Author	Year	Subjects	Age range	Level	Comments
Wood and Lipscomb	1972	···	···	up to 124 dBA max	NBS 9A coupler
Katz *et al.*	1982	···	···	110–128 dBA max	NBS 9A coupler
Kuras and Findlay	1974	25	18–25	88.1, 92.7 dBA	
Davis *et al.*	1985	22	21–22	74.2–85.5 dB SPL	ear canal measures
Catalano and Levin	1985	154	18–21	up to 114 dBA	10% of S's had TWA's of 100 dBA or greater
Rice *et al.*	1987	> 60	not reported	50% > 85 dBA eq	calculated field levels from Kemar measures
Rice *et al.*	1987	750	13–19	10% > 87 dBA eq	calculated field levels from Kemar measures
Lee *et al.*	1985	16	college age	90–104 dB SPL	

was the main activity the average level was 83.3 dB SPL (s.d. = 9.31). Eliminating classical music from the repertoire raised the average level to 85.3 dB SPL. Only one listener out of 22 selected a level that exceeded 100 dB SPL.

Catalano and Levin (1985) administered a questionnaire concerning preferred volume settings and weekly exposure in hours for PSSs in 154 college students in New York City. Sound levels for each volume setting for three popular PSS models were determined on an artificial ear, and a calculation of daily noise dose was obtained and compared to OSHA standards. It was reported that the three cassette players produced levels ranging from 60 dBA at volume setting "1" to 110–114 dBA at volume setting "10." Using the OSHA 90 dBA TWA as a standard, it was found that 29.2% of the females and 41.2% of the males exceeded 100% of the permissible exposure level; 10.1% of the subjects had TWAs of 100 dBA or greater (400% dose). It was concluded that PSSs present a hazard to hearing for a substantial proportion of young listeners.

Lee *et al.* (1985) asked 16 volunteers who regularly used PSSs to listen to "rock" or "fusion" music for a period of 3 h at their "preferred maximum level." Audiograms were obtained for each subject before and after the listening sessions. Headphone output in dB SPL, measured on an artificial ear with a NBS 9A coupler, varied from 90–104 dB SPL. Nine subjects experienced no significant TTS; the average output of the headphones was 92 dB SPL in this group. Six additional subjects had TTSs of 10 dB at one or more frequency; the average headphone output in this group was 99 dB SPL. One subject, with a headphone output of 104 dB SPL, sustained a 35 dB TTS in the right ear at 4 kHz.

Rice *et al.* (1987) described a technique to express listening levels of PSSs in terms of the free-field equivalent continuous A-weighted sound pressure levels by applying a transfer function to the levels obtained on an acoustic mannikin. Expressed this way, the levels could be compared to damage risk criteria that are based upon free-field measures of sound level. A survey of more than 60 users who regularly listened to music and speech indicated a mean listening level of 85 dBAeq; 25% of users experienced levels of at least 90 dBA and 5% levels above 100 dBA. An analysis of exposure patterns indicated that some 5% of the sample were exposed to a daily 8-h level that exceeded 90 dBA. In a follow-up study, Rice *et al.* (1987) determined incidence of PSS use and listening habits in 750 school children in Italy and England. It was found that 10% of the subjects had daily noise exposure doses of at least 87 dBA; 20% of the subjects reported sensations of fullness or ringing after listening sessions. Rice *et al.* concluded that the risk of hearing performance decrement following regular listening through PSSs for 10 years, according to British standards, was 1 in 1500. Although this analysis suggested minimal risk, Rice *et al.* cautioned that users experiencing symptoms reduce the volume of their PSS.

The study of PSS use in an industrial facility cited above (Skrainar *et al.*, 1987) showed that PSS use resulted in an increase in time-weighted average sound level of approximately 1.9 dBA (86.6 dBA to 88.5 dBA). It was concluded that on-the-job listening to PSSs did not contribute significantly to occupational noise-induced hearing loss. On the other hand, in an analysis of hearing levels of shipyard workers in Japan, Mori (1985) showed average listening levels to American rock music of 93 dBA and for Japanese music of 75 dBA; hearing levels were significantly worse in listeners versus nonlisteners of rock music.

In summary, there seems to be a consensus that PSSs are capable of producing hazardous sound levels to the ear, that if used at maximum levels for prolonged periods, pose a risk of causing NIHL. However, a number of studies that evaluated preferred listening levels and frequency of use indicate that concern is warranted for only those few listeners who prefer listening at maximum levels for extended periods of time.

III. NOISE AROUND THE HOME

There is a dearth of literature concerning noise levels of common household devices and assessment of risk of NIHL. According to Davis *et al.* (1985) their discussions with manufacturers revealed a genuine reluctance to release product noise data for fear of starting a "quietness" war that would result in increased costs without appreciable product improvement. In addition, inspection of Fig. 1 suggests that although household items may be considered annoying, sound levels and typical exposure durations do not imply any particular hazard. However, a few common household devices produce levels that are of concern.

One new and noisy product now commercially available is the gasoline-powered leaf blower. Measurements were made of the sound level recorded at the position of the ear of a listener from a Weed Eater model 1920 leaf blower with a Quest model M-27 noise logging dosimeter. Most of the noise was concentrated in the region 100–2000 Hz, and the maximum level was 110–112 dBA; the equivalent A-weighted sound level (L eq) was 103.6 dB A. The L avg (80-dB threshold, 5-dB trading ratio) was 102.6 dB; a 1.5-h daily exposure at this level would be a violation of the OSHA standard.

Another source of significant noise around the home is noise from chainsaw operations. Schmidek and Carpenter (1974) reported levels of up to 116 dBA during cutting operations with five different types of chainsaws. At idle, the saws produced levels of 91–98 dBA measured at the ear of the operator. Clearly, hearing protection should be worn by anyone using chain saws. However, unless an individual operates a chain saw regularly for prolonged periods of time (for example, cuts several cords for firewood each winter), there is probably little risk significant hearing loss from the chainsaw operation alone.

One household device that has been clearly linked to noise-induced hearing loss is the cordless telephone. Several studies (Singleton *et al.*, 1984; Gerling and Jerger, 1985; Orchik *et al.*, 1985, 1987) have concluded that cordless telephones pose a significant risk for producing acoustic trauma. These conclusions are based upon spectral analysis of the ring signal of several cordless telephones, which indicated sound-pressure levels of approximately 140 dB, and case reports from individuals who have sustained permanent hearing losses after single exposure incidents.

IV. HUNTING AND TARGET SHOOTING

It is well known that individuals exposed to gunfire may sustain hearing loss associated with those exposures. Reported peak sound levels (PSPL) from rifles and shotguns have ranged from 132–139 dBA for .22 caliber rifles (Acton *et al.*, 1966); 163- to 170-dBA peak for Mauser pistols (Axelsson *et al.*, 1981), to 150–165 dBA reported for 12-gauge shotguns (Davis *et al.*, 1985). Odess (1972) has provided a detailed analysis of noise produced by various types of sport rifles and shotguns; he found levels ranging from 163.2-dB PSPL to 172.5-dB PSPL for shotguns, and levels from 143.5-dB PSPL to 170.5 PSPL for rifles. Clinical reports concerning hearing loss following exposure to shooting can be found in the literature since the 1800's; Toynbee (1860) noted an association of asymmetrical high-tone hearing loss in patients engaging in the sport of shooting. He also properly identified asymmetrical pattern of exposure caused by shouldering the gun on the right, thus producing a head shadow that protects the right ear.

Numerous studies have attempted to assess the prevalence of hunting or target shooting in the general population. Estimates range from 14% in Scandinavian countries and in the U.K. (Axelsson *et al.*, 1981; Davis *et al.*, 1985) to 69% in the United States (Kramer and Wood, 1982). An assessment of shooting history as part of a company hearing conservation program in Canada (Chung *et al.*, 1981), indicated that 49.5% of the workforce responded positively to questions concerning hunting, target shooting, or pistol shooting. These results are generally consistent with other findings from US industry (Clark *et al.*, 1987).

One method of determining the role of shooting on hearing loss is to compare audiometric data in groups of individuals who engage in shooting with a matched group who do not. Variations of such an approach have been reported by numerous investigators. Taylor and Williams (1966) compared hearing levels of 103 sports hunters with 21 physicians who were not exposed to shooting noise. For all age groups, sports hunters were found to have significantly worse hearing than the control group at all frequencies from 3–8 kHz; in addition, hearing levels in the left ear were significantly worse than the right. Graphs showing median hearing levels of hunters and controls 40–49 years old are shown in Figs. 5 and 6. The data from the control population indicate slightly worse hearing in the left ear (4 dB at 3,4, and 6 kHz); in the hunters the left ear was 26 dB worse at 3,4, and 6 kHz. Note that the maximum effect of shooting appears at 6 kHz rather than 4 kHz.

Similar findings have been reported by Chung *et al.* (1981), Johnson and Riffle (1982), and by Prosser *et al.* (1988). Chung *et al.* (1981), in a study of 29 953 individuals with shooting histories obtained from an industrial audiometric database reported significant asymmetries in hearing levels with the left ear worse for all test frequencies above 2 kHz. In the Chung study, 13% of the shooters shouldered their weapon on the left, and the data for these individuals showed a right-ear asymmetry. Other studies that fail to consider shouldering preferences may underestimate the true asymmetrical nature of the exposure.

Johnson and Riffle (1982) evaluated the hearing levels of 68 pairs of workers, matched for sex, age, and exposure level, selected from the interindustry noise study. For each pair, one of the individuals had indicated exposure to nonoccupational gunfire during the previous year. Differences in mean hearing level between male subjects exposed to gunfire and those not exposed were clearly apparent and varied between 9 and 16 dB for the frequencies of 3000, 4000, and 6000 Hz. No significant differences were found in thresholds of female shooters; this was attributed to the fact that most females fired guns of small caliber (.22), while most males tended to use several types of guns of larger calibers. Johnson and Riffle concluded that nonoccupational exposure to noise may be a significant problem for men and can be considered

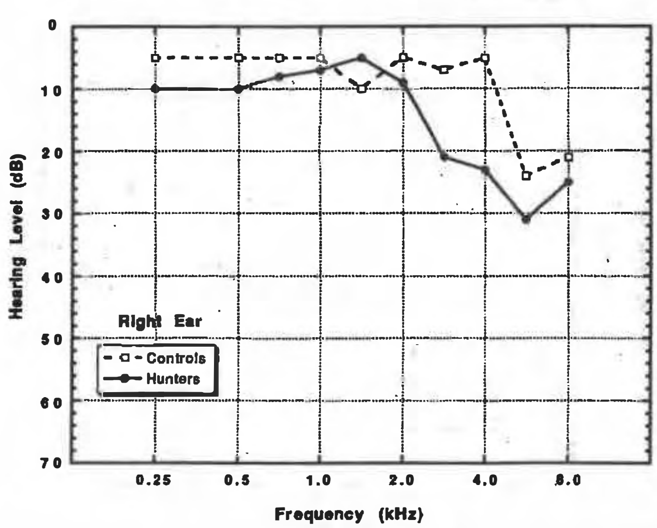

FIG. 5. Median hearing levels for the right ears of a control group (dashed line; $N = 9$) and sports hunters (solid line; $N = 32$) ages 40–49 years. [Data replotted from Taylor and Williams (1966).]

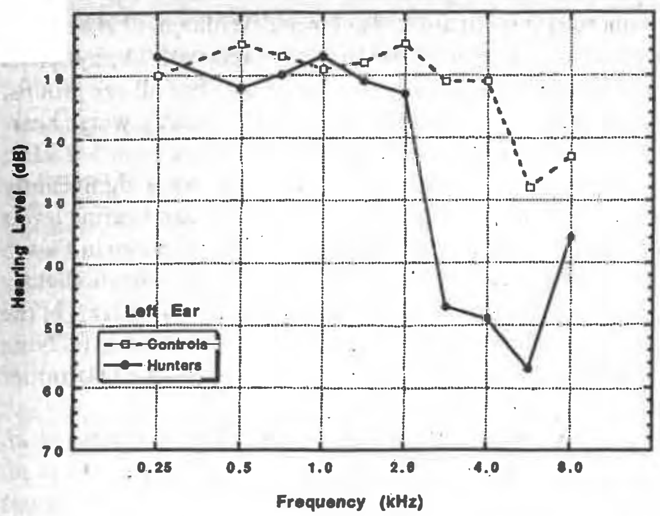

FIG. 6. Median hearing levels for the left ears of a control group (dashed line; $N = 9$) and sports hunters (solid line; $N = 32$) ages 40–49 years. [Data replotted from Taylor and Williams (1966).]

equivalent in effect to an occupational exposure of 89 dBA, 8 h per day, for 20 years.

In a recent study, Prosser *et al.* (1988) compared hearing level data for 133 Italian railway workers who also hunted for sport with that of 82 age-matched nonhunting colleagues. Hunters were found to differ from nonhunters by having significantly worse hearing thresholds in the ear contralateral to the shoulder supporting the firearm. Data for the 36- to-45-year-old shooters and nonshooters are shown in Fig. 7. Note that the data for the right and left ears of the nonshooters and the right ears of shooters are quite similar. However, the hearing in the left ear of the shooters was about 15 dB worse than the other thresholds at 3, 4, and 8 kHz. The interaural threshold difference at 4 kHz was related to the number of rounds fired and exposure duration. Prosser *et al.* concluded that the interaural difference could be used as an estimate of the effects of nonoccupational (i.e., shooting) noise to which hunters have been exposed.

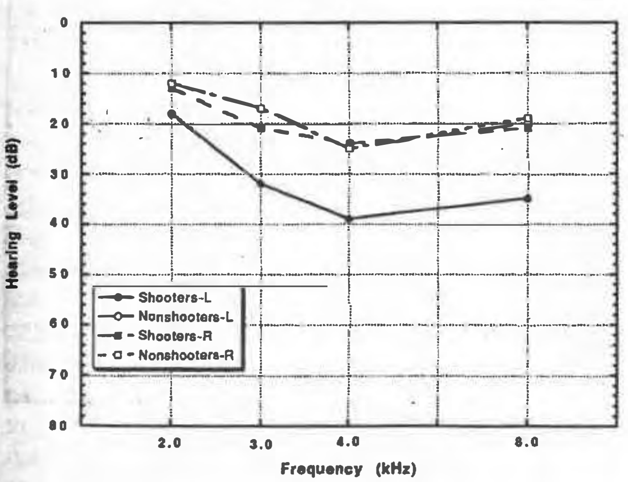

FIG. 7. Comparison of hearing levels for 36- to 45-year-old shooters and nonshooters. [Data adapted from Prosser *et al.* (1988).]

The papers reviewed above exclude the literature concerning exposure to noise during military service, which is considered an occupational exposure. However, the data from studies of the effects of avocational shooting support the following statements.

(1) Large caliber rifles and shotguns produce exposure levels that are sufficient to cause acoustic trauma in some individuals.

(2) Workers in noisy industries who engage in sport shooting may develop additional hearing losses due to gunfire noise over whatever loss they may sustain because of occupational exposure.

(3) It is reasonable to estimate that 50% of U.S. industrial workers are exposed to gunfire noise from hunting or target shooting.

(4) Threshold differences between the ear ipsilateral to the firearm and contralateral to it are typically 15 dB for high-frequency (3–8 kHz) stimuli and can be as high as 25–30 dB for frequent shooters.

ACKNOWLEDGMENTS

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Abrol, B. M, Nath, L. M., and Sahai, A. N. (**1970**). "Noise and acoustic trauma: Noise levels in discotheques in Delhi," Int. J. Med. Res. **58**, 1758–1763.

Acton, W. I., Coles, R. R. A., and Forrest, M. R. (**1966**). "Hearing hazard from small-bore rifles," The Rifleman (Dec.) (cited in Davis *et al.*, 1985).

Axelsson, A., and Lindgren, F. (**1977**). "Does pop music cause hearing damage?," Audiology **16**, 432–437.

Axelsson, A., and Lindgren, F. (**1981**). "Hearing in classical musicians," Acta. Otolaryngol. Suppl. 377, 3–74.

Axelsson, A., Jerson, T., and Lindgren, F. (**1981**). "Noisy leisure time activities in teenage boys," Am. Ind. Hyg. **42**, 229–233.

Barry, J. P., and Thomas, I. B. (**1972**). "A clinical study to evaluate rock music, symphonic music and noise as sources of acoustic trauma," J. Aud. Eng. Soc. **20**, 271–274.

Bickerdike, J., and Gregory, A. (**1980**). "An evaluation of hearing damage risk to attenders at discotheques," Leeds Polytechnic. School of Constructional Studies. Dept. Environment Report (cited in Davis *et al.*, 1985).

Burns, W., and Robinson, D. W. (**1970**). *Hearing and Noise in Industry* (Her Majesty's Stationary Office, London)

Calvert, D. R., and Clark, W. W. (**1983**). "The social noise phenomenon," in *Newsnotes* (Central Institute for the Deaf, St. Louis, MO).

Catalano, P. J., and Levin, S. M. (**1985**). "Noise-induced hearing loss and portable radios with headphones," Int. J. Ped. Otorhinolaryngol. **9**, 59–67

Chung, D. Y., Gannon, R. P., Willson, G. N., and Mason, K. (**1981**). "Shooting, sensorineural hearing loss, and workers' compensation," J. Occup. Med. **23**, 481–484.

Clark, W. W. (**1991**). "Recent studies of temporary threshold shift (TTS) and permanent threshold shift (PTS) in animals," J. Acoust. Soc. Am. **90**, 155–163.

Clark, W. W., and Bohne, B. A., (**1984**). "The effects of noise on hearing and the ear," Med. Times **122**, 17–22.

Clark, W. W., and Bohne, B. A. (**1986**). "Temporary hearing losses following attendance at a rock concert," J. Acoust. Soc. Am. Suppl. 1 **79**, S48.

Clark, W. W., Bohl, C. D., Davidson, L. S., and Melda, K. (**1987**). "Evaluation of a hearing conservation program at a large industrial company," J. Acoust. Soc. Am. Suppl. 1 **82**, S113.

Danenberg, M. A., Loos-Cosgrove, M., and LoVerde, M. (**1987**). "Temporary hearing loss and rock music," Lang. Speech Hear. Serv. Schools **18**, 267–274.

Davis, A. C., Fortnum, H. M., Coles, R. R. A., Haggard, M. P., and Lutman, M. E. (1985). "Damage to hearing from leisure noise: A review of the literature," MRC Institute of Hearing Research, University of Nottingham, Nottingham NG7 2RD.

Department of Labor Occupational Noise Exposure Standard (DOL) (1983). Code of Federal Regulations, Title 29, Chapter XVII, Part 1910, subpart G, 48FR 9776.

Dey, F. L. (1970). "Auditory fatigue and predicted permanent hearing defects from rock and roll music," New Eng. J. Med. 282, 467–470.

Fearn, R. W. (1972). "Noise levels in youth clubs," J. Sound Vib. 22, 127–131.

Fearn, R. W. (1975). "Level limits of music," J. Sound. Vib. 43, 588–591.

Flottorp, G. (1973). "Music—A noise hazard?," Acta Otolaryngol. 75, 345–347.

Flugrath, J. M. (1968). "Modern-day rock-and-roll music and damage-risk criteria," J. Acoust. Soc. Am. 45, 704–711.

Gerling, I. J., and Jerger, J. F. (1985). "Cordless telephones and acoustic trauma: A case study," Ear Hear. 6, 203–205.

Hickling, S. (1970). "Noise-induced hearing loss and pop music," New Zealand J. Med. 282, 467–470.

Johnson, D. L. (1978). "Derivation of presbycusis and noise induced permanent threshold shift (NIPTS) to be used for the basis of a standard on the effects of noise on hearing," Aerospace Medical Research Laboratory Rep. AMRL-TR-78-128, Wright-Patterson Air Force Base, Ohio.

Johnson, D. L., and Riffle, C. (1982). "Effects of gunfire on hearing level for selected individuals of the inter-industry noise study," J. Acoust. Soc. Am. 72, 1311–1314.

Katz, A. E., Gerstman, H. L., Sanderson, R. G., and Buhanan, R. (1982). "Stereo earphones and hearing loss," (Letter), New Eng. J. Med. 307, 1460–1461.

Kramer, M. B., and Wood, D. (1982). "Noise-induced hearing loss in rural schoolchildren," Scand. Audiol. 11, 279–280.

Kryter, K. D. (1986). *Effects of Noise on Man* (Academic, New York).

Kuras, J. E., and Findlay, R. C. (1974). "Listening patterns of self-identified rock music listeners to rock music presented via earphones," J. Aud. Res. 14, 51–56.

Lebo, C. P., and Oliphant, K. P. (1968). "Music as a source of acoustic trauma," Laryngoscope 78, 1211–1218.

Lee, P. C., Senders, C. W., Gantz, B. J., and Otto, S. R. (1985). "Transient sensorineural hearing loss after overuse of portable headphone cassette radios," Otolaryng. Head Neck Surg. 93, 633–625.

Lipscomb, D. M. (1969). "Ear damage from exposure to rock-and-roll music," Arch. Otolaryng. 90, 29–39.

Melnick, W. (1991). "Human temporary threshold shift (TTS) and damage risk," J. Acoust. Soc. Am. 90, 147–154.

Mori, T. (1985). "Effects of record music on hearing loss among young workers in a shipyard," Int. Arch. Occup. Environ. Health 56, 91–97.

Odess, J. S. (1972). "Acoustic trauma of sportsman hunter due to gun firing," Laryngoscope 82, 1971–1989.

Orchik, D. J., Schmaier, D. R., Shea, J. J. Jr., Emmett, J. R., Moretz, W. H., Shea, J. J., III. (1987). "Sensorineural hearing loss in cordless telephone injury," Otolaryngol. Head Neck Surg. 96, 30–33.

Orchik, D. J., Schumaier, D. R., Shea, J. J, and Moretz, W. H. (1985). "Intensity and frequency of sound levels from cordless telephones," Clin. Pediat. 24, 688–690.

Prosser, S., Tartari, M. C., and Arslan, E. (1988). "Hearing loss in sports hunters exposed to occupational noise," Brit. J. Audiol. 22, 85–91.

Redell, R., and Lebo, C. P. (1972). "Ototraumatic effects of hard rock music," Calif. Med. 116, 1–4.

Rice, C. G., Breslin, M., and Roper, R. G., (1987). "Sound levels from personal cassette players," Brit. J. Audiol. 21, 273–278.

Rice, C. G., Rossi, G., and Olina, M. (1987). "Damage risk from personal cassette players," Brit. J. Audiol. 21, 279–288.

Rintelmann, W. F., and Borus, J. F. (1968). "Noise-induced hearing loss and rock-and-roll music," Arch. Otolaryngol. 88, 377–385.

Rintelmann, W. F., Lindberg, R. F., and Smitely, E. K. (1972). "Temporary threshold shift and recovery patterns from two types of rock-and-roll music presentation," J. Acoust. Soc. Am. 51, 1249–1255.

Rupp, R. R., Banachowski, S. B., and Kiselwich, A. S. (1974). "Hard rock music and hearing damage risk," Sound Vib. 8, 24–26.

Schmidek, M., and Carpenter, P. (1974). "Intermittent noise exposure and associated damage risk to hearing of chain saw operators," Am. Ind. Hyg. J. 35, 152–158.

Singleton, G., Whitaker, D., Keim, R., and Kemker, F. (1984). "Cordless telephone: A threat to hearing," Ann. Otol. Rhinol. Laryngol. 93, 565–568.

Skrainar, S. F., Royster, L. H., Berger, E. G., and Pearson, R. G. (1987). "The contribution of personal radios to the noise exposure of employees at one industrial facility," Am. Ind. Hyg. Assoc. J. 48, 390–395.

Taylor, W., Pearson, J., Mair, A., and Burns, W. (1965). "Study of noise and hearing in jute weaving," J. Acoust. Soc. Am. 38, 113–120.

Taylor, G. D., and Williams, E. (1966). "Acoustic trauma in the sports hunter," Laryngoscope 76, 863–879.

Toynbee, J. (1860). *Diseases of the Ear: Their Nature, Diagnosis, and Treatment* (Churchill, London).

Ulrich, R. F., and Pinheiro, M. L. (1974). "Temporary hearing losses in teenagers attending repeated rock-and-roll sessions," Acta Otolaryngol. 77, 51–55.

Wood, W. S., and Lipscomb, D. M. (1972). "Maximum available sound-pressure levels from stereo components," J. Acoust. Soc. Am. 52, 484–487.